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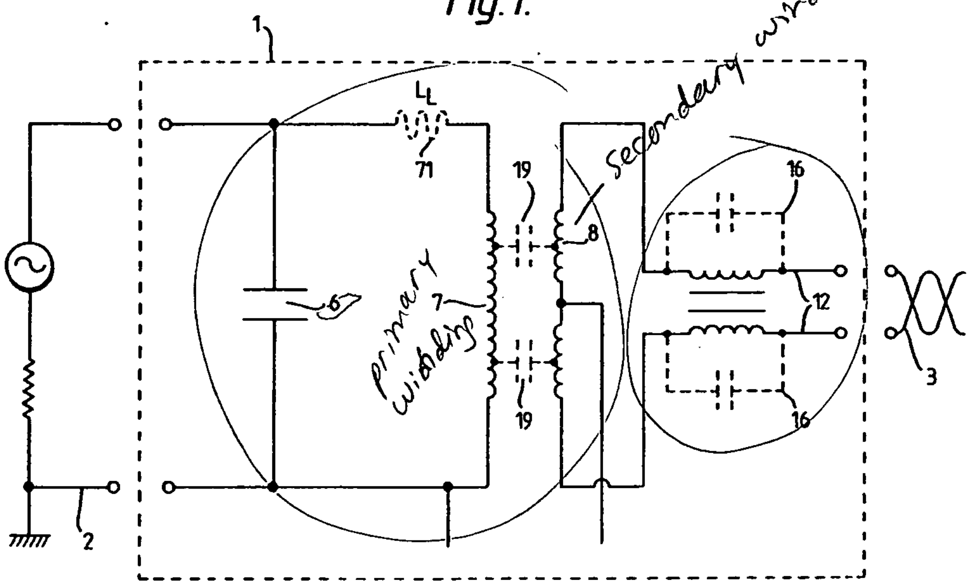
(54) **Balance-unbalance interface**

(57) Interface apparatus for coupling unbalanced terminal circuitry to a balanced cabling system. The interface enabling the associated data wiring scheme to meet British standard 6527 A. The apparatus uses a balun with a common mode filter connected between the balun and the balanced line. The inteface may be band-width limited.

Fig. 1.



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig.1.

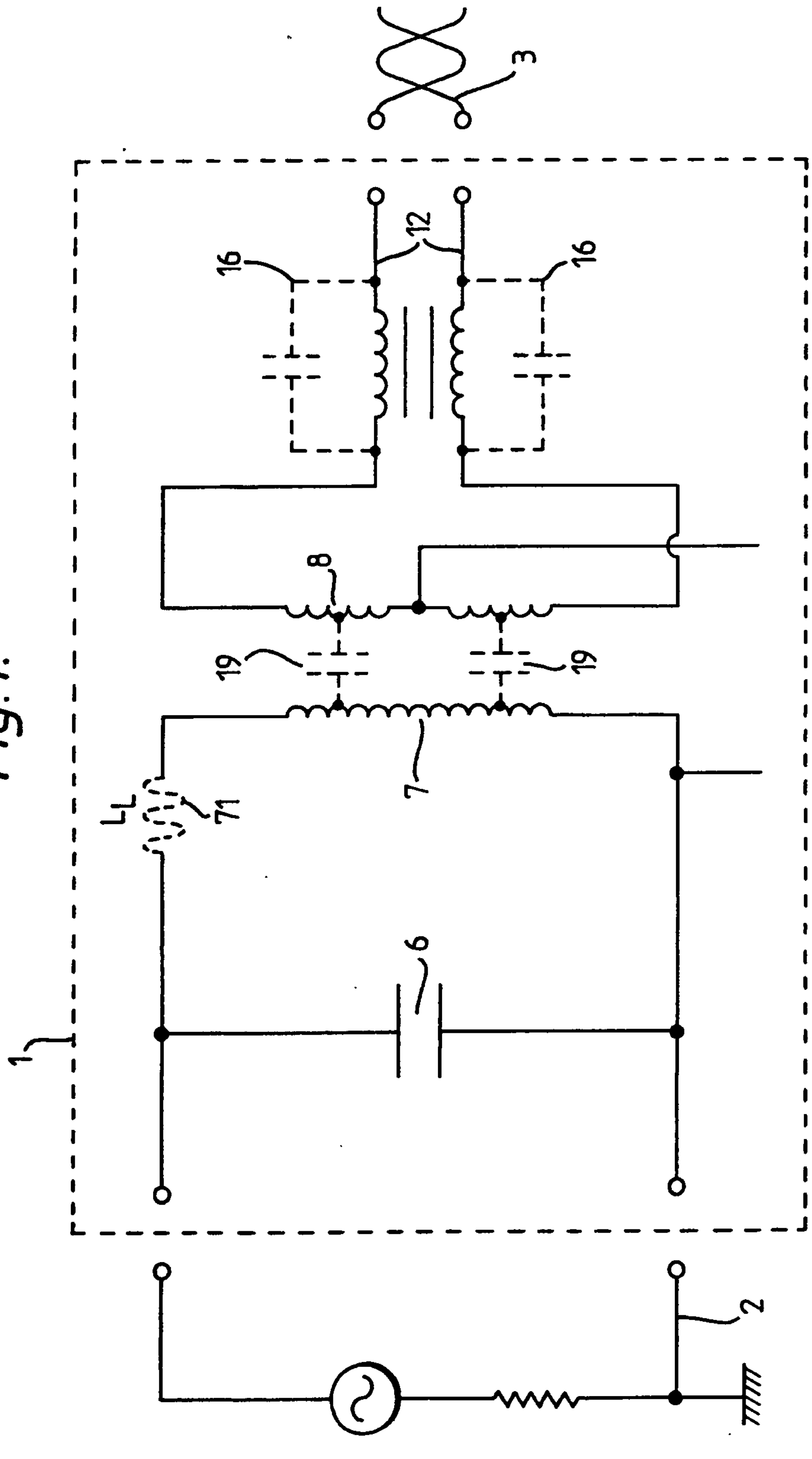


Fig.2a

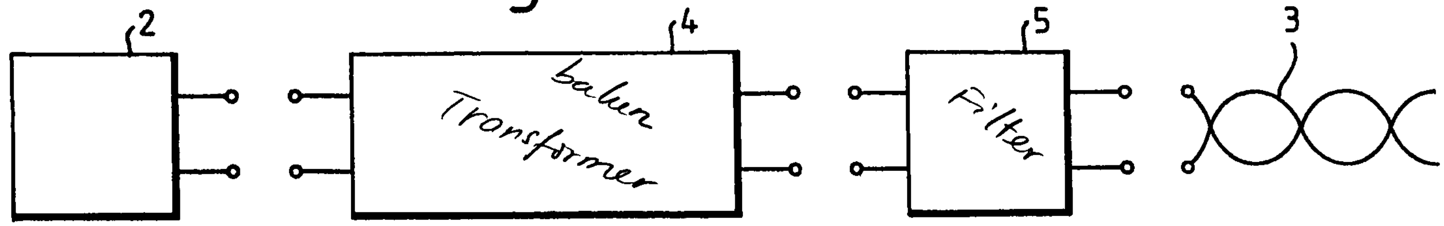


Fig.2b

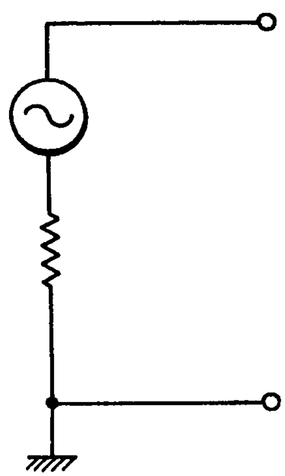


Fig.2c

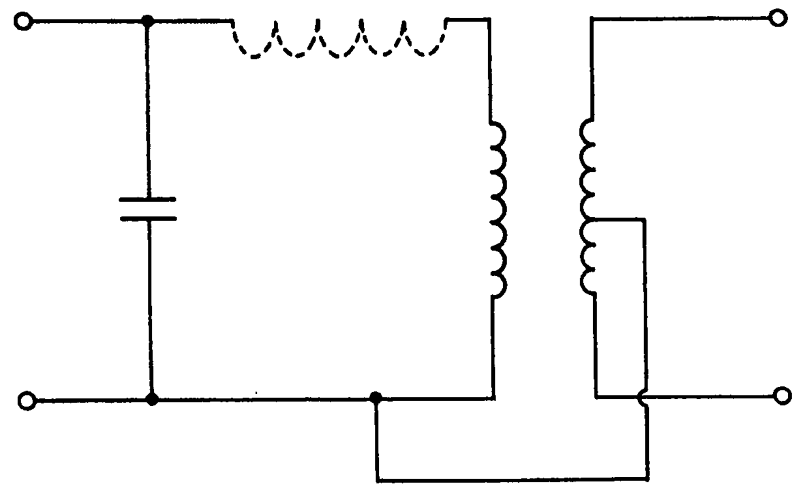
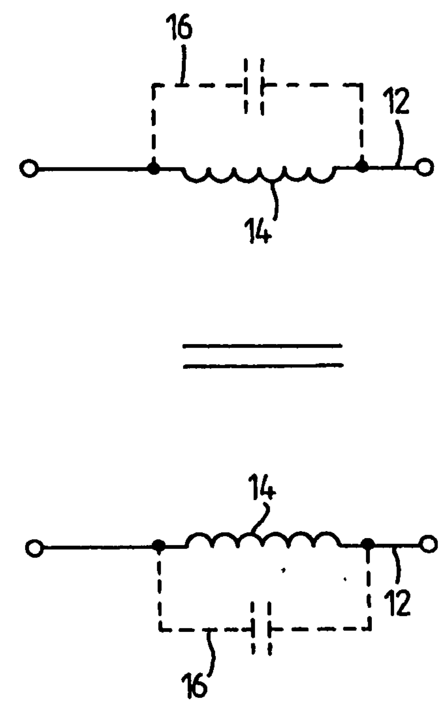


Fig.2d



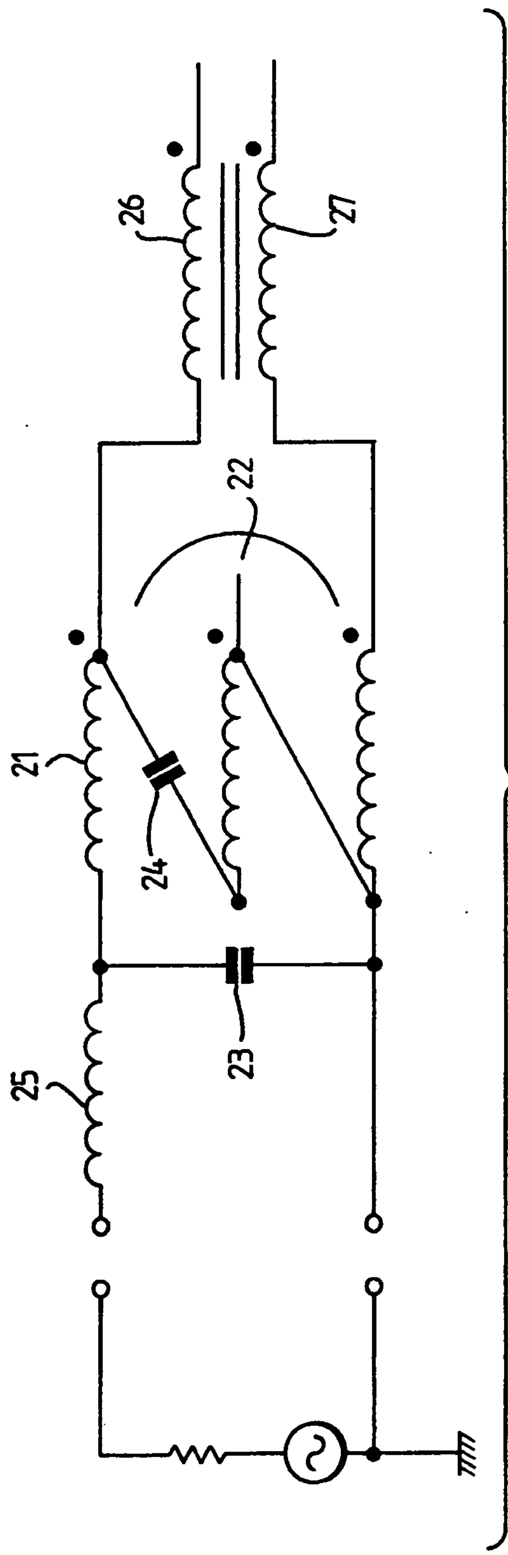


Fig. 3.

INTERFACE APPARATUS

This invention relates to interface apparatus for coupling unbalanced terminal circuitry to a balanced cabling system, and in particular for coupling workstation facilities to open architecture building data wiring systems.

Traditionally copper co-axial cable is used for carrying data signals in excess of 1 MHz This offers good transmission over distances, and a high level of protection against data corruption.

It is not unusual for a multi-storey office block to be equipped with workstation facilities at each desk. In this case, the complete building needs to be wired up, and the workstations need to be moveable within the building. The traditional co-axial wiring schemes are costly, bulky and not well suited to frequent reconfiguration which may be necessary in modern open plan offices.

Data signals can also be carried by unshielded, twisted pair, data grade cables and this offers an elegant, flexible, low cost solution to data transmission, as a twisted pair is an inherently balanced configuration. Twisted pairs also require less duct space than co-axial cable.

The system performance of a twisted pair data cabling 3scheme carrying data typically in the range 1 to 16 Mb/s is critically dependent on a number of technical parameters including system balance, data rate and the frequency spectrum of the data signal. With the high data rates involved, failure to address these issues

adequately results in a system which both radiates and is susceptible to radio fr quency interferenc (RFI).

Equipment designed to work in a co-axially cabled environment typically presents the data port on a computer or workstation with an unbalanced interface. This facilitates direct connection to a co-axial circuit. Where it is desired to operate with a twisted pair cable however, an unbalanced signal source is totally unsuitable, because under these conditions, the twisted pair will be susceptible to external noise and will itself radiate the transmitted data. However, if the signal source is balanced, that is both the signal voltages and the source impedances fulfil balanced conditions, each wire of the pair will in principle carry an equal and opposite signal, and the radiations emitted by the wires will cancel out. Similarly, noise coupled into the system will also cancel out. Perfect balance can in practice never be achieved, so there will always be some residual radiated fields. The radiated fields can be reduced to acceptable levels with careful design. At higher operating frequencies, balance becomes harder to achieve as the effects of stray reactances increase with frequency.

The susceptibility of a device or circuit is the capability of the device or circuit to respond to unwanted electrical energy (noise).

A differential mode signal in a balanced, three terminal system, is the signal applied between its two ungrounded terminals.

A common mode signal is a signal applied to both terminals of a differential circuit and occurs where the source signal on each branch is equal but not opposite leaving a "net out of balance" or common mode signal. A definition of common mode voltage is an equal voltage on both conductors with reference to ground.

A balanced circuit is a two conductor circuit in which both conductors and all circuits connected to them have the same impedance with respect to ground and to all other conductors. The purpose of balancing is to make noise pickup equal in both conductors, in which case it will be a longitudinal or common noise signal which can be filtered out.

A balun is a balancing transformer, sometimes called a neutralising transformer, used to couple a balanced impedance such as a twisted pair transmission line, to an unbalanced transmission line such as a length of co-axial cable. The balun prevents assymmetrical loading of the balanced impedance. A balun is, therefore, useful as an interface between a balanced and an unbalanced circuit in order to convert the signal to a balanced mode.

Circuit balance also depends on the operating frequency. Normally, the higher the frequency the harder it is to obtain good balance, because stray reactances have more effect on the circuit balance at high frequency.

In order to develop a system which is compliant with BS6527 Class A, which is the British Standard for limits and methods of measurement of radio interference characteristics, and which is not susceptible to data corruption from external RFI, it is essential to maintain a high degree of system balance, and to deal adequately with the longitudinal noise which is the voltage associated with the common mode currant coupled into the data circuit. These requirements can only be met by tightly controlling the specification of the cable used, and by using a suitable interface between the unbalanced terminal circuitry and the balanced cabling system.

An ideal balun will pass the desired incoming differential data signal while ensuring that any common

mode signal present, perhaps as a result of cross-talk or external RFI will be blocked.

If an ideal transformer were available this would not be a difficult task.

In practice, stray capacitance and inductance will limit the degree to which the ideal is achieved. In particular some of the incoming unwanted common mode signal would be converted to differential mode and thus corrupt the desired data. The majority of the commercially available baluns do not enable a data wiring system to meet the British Standard 6527 Class A on RFI emissions.

The aim of this invention is to provide a reliable interface between a balanced circuit and an unbalanced circuit. Thus maximising the distance over which data can be reliably transmitted and allows the associated data wiring scheme to meet BS6527 Class A and to meet test requirements in accordance with DEF STAN 59-41 for RFI susceptibility.

The present invention provides an apparatus for providing an interface between a balanced circuit and an unbalanced circuit, the apparatus comprising a balun and a common mode filter, wherein the common mode filter is connected between the balun and the balanced circuit.

Preferably the balun is band-width limited, and the common mode filter is a choke.

Preferably the common mode filter has a low insertion loss, while providing good blocking characteristics to common mode signals in the range 1 MHz to 100 MHz.

Preferably the balun is a transformer with primary and secondary windings and a transformer core.

In a preferred embodiment, the balun transformer has a high permeability core. Conveniently the secondary coil on the transformer is centre tapped. It is preferable to limit the differential signal band-width of

the balun. It is beneficial to use bifilar windings on the secondary winding of the transformer in order to balance the stray capacitances. In the case of the common mode filter performance is maximised by using a low number of bifilar windings, typically four turns, which minimises leakage inductance and self capacitance.

In another preferred embodiment the transformer is a transmission line transformer. Conveniently, the balun transformer comprises a trifilar winding on a toroidal core, allowing transmission at frequencies of up to 16MHz whilst maintaining d.c. continuity.

The invention also provides a method of interfacing a balanced circuit and an unbalanced circuit the method comprising using a balun and a common mode filter, wherein the common mode filter is situated between the balun and the balanced circuit.

Two forms of interface unit each of which is constructed in accordance with the invention will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a circuit diagram of the first form of interface unit;

Figure 2a is a block diagram of the interface unit of Figure 1;

Figures 2b, 2c and 2d show the parts of the circuit diagram to which each block in Figure 2a relates; and

Figure 3 is a circuit diagram of the second form of interface unit.

Referring to the drawings, Figure 1 shows an interface unit 1 positioned between an unbalanced signal source 2 and a balanced cable 3 constituted by a twisted pair. As shown in Figure 2, the interface unit 1 comprises a transformer (balun) 4 and a common mode filter 5. The transformer 4 consists of a primary winding 7 and a secondary winding 8. The primary winding

7 has approximately 10 turns and an inductance of 800μH. The secondary winding 8 of the transformer 4 is centre-tapped. ~~The transformer 4 has a 200pF capacitor 6~~ in parallel with the primary winding 7, and a leakage inductance 71 which appears in series with the primary winding 7 and which has a critical effect on circuit performance. The leakage inductance 71 is in the region of 300mH. ~~There are two elements of stray capacitance 19~~ between the primary winding 7 and the secondary winding 8. The secondary winding 8 is tapped at the centre to improve the circuit balance by ensuring that the unwanted ccommon mode voltage appears equally across both halves of the secondary winding causing equal and opposite currents to flow in the two halves of the secondary winding Therefore, the induced voltages in the primary winding 7 resulting from the common mode voltage will cancel out.

~~The capacitor 6~~ determines the high frequency cut-off point which is typically 8 MHz or higher. The low frequency cut-off point is an inherent function of the transformer 4, the main design requirement being to keep the inductance of the primary winding high enough, that is with enough turns, to support the lowest part of the required frequency spectrum. By limiting the high frequency and low frequency cut-off points, the interface unit is band-width limited. The actual high frequency cut-off is chosen to allow the essential part of the frequency spectrum through, so as to prevent unnecessary high frequency harmonics from reaching the twisted pair, as these are the ones which radiate most freely.

Moreover because the circuit of the interface unit is band-width limited, the insertion loss of the common mode filter is very low throughout the operating band-width, but it provides good blocking characteristics to common mode signals from about 1 MHz to well above 100 MHZ.

The secondary winding 8 is connected to the common mode filter 5. The common mode filter 5 consists of two inductances, which are bifilar, wound on a single core to ensure close coupling, ~~the common mode filter 5 has self capacitances 16 in parallel across both branches 12 of the common mode filter~~. The self capacitances 16 are of the order of 1pF or less. ~~The common mode filter 5 filters out any common mode signals passing through the interface unit which would result in emissions from the twisted pair which would impact on susceptibility~~. Stray capacitances 19 occur between the primary and secondary windings 7 and 8, of the transformer 4. These stray capacitances add up to approximately 6pF in this case.

The differential signal passes from the source 2 into the interface unit, where it is transformed by the transformer 4 from an unbalanced signal on the primary winding 7 to two equally opposing signals one on each half of the secondary winding 8, thus providing a balanced signal to be fed into the common mode filter 5, and eventually to the twisted pair 3, so that any RFI caused by these signals will cancel out. To any longitudinal (common mode) noise current the impedance of the common mode filter 5 is high, so only the differential signal is passed.

~~Figure 2a~~ shows in block form an unbalanced circuit 2, the balun 4 an unbalanced cable 3 denoted by a twisted pair shows the common mode filter 5. Figures 2b, 2c and 2d show the parts of the circuit corresponding to these blocks.

Figure 3 which shows an example of a transmission line transformer interface unit 20, which comprises a transformer (balun) 21 wound onto a toroidal core (not shown), typically ferrite, as a trifilar winding 22. This design allows successful transmission of data up to a frequency of 16 MHz over a twisted pair, whilst

maintaining d.c. continuity through th interfac unit 20. The trifilar winding 22 has a very low leakage inductance and thus a high cut-off frequency, typically in excess of 200 MHz. The cut-off frequency is brought down to 30 to 45 MHz, which is the cut-off frequency needed for transmission of data up to 16 MHz, using a 100pF shunt capacitor 23 to limit the band-width. A ferrite bead 25 provides a series inductance. Two 800μH inductors 26 and 27 form the common mode filter at operating frequencies.

D.C. continuity is provided by a 0.1μF capacitor 24 which prevents a short circuit across the balun at d.c. voltages. This is situated between the first and second windings on the transformer 21. The capacitor 24 has a negligible effect on the performance of the interface unit 20 at operating frequencies. At lower frequencies, typically 1 kHz down to d.c., the impedance of capacitor 24 is sufficiently large so that open circuit, the trifilar wound transformer 21 is then effectively two windings which act as a common mode choke at low frequencies and at d.c. the remaining two windings act as a pair of wires.

The interface units would be useful for interfacing with IBM3270, IBM System 36, IBM A3400 and Wang VS Computer Systems for example. Which configuration is used in practice will depend on the operating requirements of the computer system in question.

The interface units described above fulfil the key requirements for a balanced signal source using a balun. Thus, each unit and its associated filtering offer a low loss to differential signals, and a high impedance to common mode signals. The impedance from each branch to ground is equal and the source signals on each branch cancel. In each case the interface unit matches the impedance of the unbalanced interface to that of the

balanced cable to minimise reflected power and prevent loss of signal strength.

As each of the units has a very good impedance and system balance low RFI emissions and good RFI susceptibility are achieved.

CLAIMS

1. An apparatus for providing an interface between a balanced circuit and an unbalanced circuit, the apparatus comprising a balun and a common mode filter, wherein the common mode filter is connected between the balun and the balanced circuit.

2. An apparatus as claimed in claim 1, wherein the apparatus is band-width limited.

3. An apparatus as claimed in claim 1 or claim 2, wherein the common mode filter is a choke.

4. An apparatus as claimed in any one of the preceding claims, wherein the common mode filter has a low insertion loss, while providing good blocking characteristics to common mode signals in the range 1 MHz to 100 MHz.

5. An apparatus as claimed in any one of the preceding claims, wherein the balun is a transformer with primary and secondary windings and a transformer core.

6. An apparatus as claimed in claim 5, wherein the balun transformer core has a high permeability.

7. An apparatus as claimed in claim 5 or claim 6, wherein the winding in the secondary winding of the balun transformer is bifilar.

8. An apparatus as claimed in any one of claims 1 to 4, wherein the balun is a transmission line transformer.

9. An apparatus as claimed in claim 5 or claim 6, wherein the transformer comprises a trifilar winding on a toroidal core.

10. An apparatus as claimed in any one of 5, 6, 7 or 9, further comprising a secondary winding on the balun which is centre tapped.

11. An apparatus substantially as hereinbefore described with reference to and illustrated by Figures 1 and 2 or 3 of the accompanying drawings.

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